

AIR BLOWN FIBER (ABF) CABLE WITH LOW COMPOSITE  
COEFFICIENT OF THERMAL EXPANSION

AN APPLICATION FOR  
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### Description

## AIR BLOWN FIBER (ABF) CABLE WITH LOW COMPOSITE COEFFICIENT OF THERMAL EXPANSION

### Technical Field

5           The present invention relates to air blown fiber (ABF) tubes. More particularly, the invention relates to an air blown fiber (ABF) tube and tube cable jacket so as to provide both a low composite coefficient of thermal expansion and minimum post-extrusion shrinkage of the air blown fiber tube cable.

### Related Art

10           Air blown fiber (ABF) tube cables installed in harsh weather environments, such as aerial outside plant cables, are subjected to extreme temperature and environmental conditions. Low temperature shrinkage will ordinarily occur in the longitudinal axis direction of the tube and cable due to  
15           the relatively high coefficient of thermal expansion characteristic of the plastic used to manufacture conventional air blown fiber (ABF) tubes and cables. Significant shrinkage in the longitudinal axis direction of air blown fiber tubes may cause induced signal attenuation due to bending of the optical fibers housed in the tubes of the air blown fiber (ABF) tube cable. The optical fibers  
20           have a significantly lower coefficient of thermal expansion than the air blown

Thus, it can be appreciated that the coefficient of thermal expansion and post-extrusion shrinkage can have detrimental effects on the performance of air blown fiber (ABF) tubes used for telecommunications. From a theoretical standpoint, the coefficient of thermal expansion and post-extrusion shrinkage of the tube should be as close to zero as possible. If the coefficient of thermal expansion and post-extrusion shrinkage of air blown fiber (ABF) tubes are not minimized through design and manufacturing, the tubes will shrink during use due to fluctuations in the temperature to which the tubes are exposed and the shrinkage can result in the aforementioned undesirable and sometimes catastrophic signal loss.

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In accordance with the present invention, applicants provide a novel air blown fiber optic tube cable with a low composite coefficient of thermal expansion. More specifically, the novel air blown fiber (ABF) optic tube cable assembly having improved thermal stability comprises an air blown fiber (ABF)

tube within which one or more air blown optical fiber units can be installed, wherein the air blown fiber (ABF) tube is formed from a cross-linked polyolefin comprising a predetermined amount of an inorganic filler material such as chopped glass fiber, glass spheres, mica, talc,  $\text{CaCO}_3$  or the like, and/or a predetermined amount of polymeric filler material such as polyaramid, liquid crystal polymers or other engineering resins. An additional ultraviolet (UV) radiation stabilizer filler may optionally be included, comprising a predetermined amount of carbon black or other suitable material which prevents deterioration of the polymer during exposure to ultraviolet (UV) radiation during the lifetime of the tube or cable. Another embodiment of the invention comprises a fiber optic cable assembly having improved thermal stability and comprising a plurality of air blown fiber (ABF) tubes within each of which one or more air blown optical fiber units can be installed wherein the air blown fiber (ABF) tubes are formed from a cross-linked polyolefin comprising a predetermined amount of inorganic filler material such as chopped glass fiber, glass spheres, mica, talc,  $\text{CaCO}_3$  or the like, and/or a predetermined amount of polymeric filler material such as polyaramid, liquid crystal polymers or other engineering resins, and optionally comprising a predetermined amount of carbon black or other suitable ultraviolet (UV) radiation stabilizer. A jacket is positioned around the plurality of air blown fiber (ABF) tubes, and the jacket is formed from cross-linked polyolefin comprising a predetermined amount of inorganic filler material such as chopped glass fiber, glass spheres, mica, talc,  $\text{CaCO}_3$  or the like, and/or a predetermined amount of polymeric filler material such as polyaramid,

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liquid crystal polymers or others engineering resins, and a predetermined amount of carbon black or other suitable ultraviolet (UV) radiation stabilizer.

It is therefore an object of the present invention to provide an improved air blown fiber (ABF) tube construction with optimized thermal stability and minimal post extrusion shrinkage.

It is another object of the present invention to provide an improved air blown fiber (ABF) tube construction wherein the cable construction has a coefficient of thermal expansion value of less than  $150 \mu\text{m}/\text{m}^\circ\text{C}$  over the temperature range of  $20^\circ\text{C}$  to  $-40^\circ\text{C}$ .

It is another object of the present invention to provide an improved air blown fiber (ABF) tube construction which substantially obviates optical fiber buckling and bending and the resulting signal loss.

Some of the objects of the invention having been stated hereinabove, other objects will become evident as the description proceeds, when taken in connection with the accompanying drawings described hereinbelow.

#### Brief Description of the Drawings

Figure 1 is a cross section of a prior art multiple tube air blown fiber (ABF) tube cable.

Figure 2 is a cross section of an air blown fiber (ABF) tube according to an embodiment of the present invention.

Figure 3 is a cross section of an air blown fiber (ABF) tube according to a second embodiment of the present invention.

Figures 4A-4D are cross sections of air blown fiber (ABF) tube cables according to a third embodiment of the invention and containing two, three, seven and nineteen tube cables, respectively.

5 Figure 5 is a cross section of an air blown fiber (ABF) tube cable according to another embodiment of the present invention that includes an optional longitudinally extending central strength member in addition to six air blown fiber (ABF) tubes.

10 Figure 6 is a cross section of an air blown fiber (ABF) tube cable according to another embodiment of the present invention that includes an optional longitudinally extending central strength member in addition to eighteen air blown fiber (ABF) tubes.

#### Description of the Preferred Embodiments

15 Preferred embodiments of the improved thermal stability air blown fiber (ABF) tube and the air blown fiber (ABF) tube cable in accordance with the present invention are described below with reference to Figures 2-6 of the drawings.

20 Referring now to Figure 1, prior art blown fiber (ABF) tubes **T** are shown that can be used alone or in an air blown fiber (ABF) tube cable **C** as depicted in Figure 1. Air blown fiber (ABF) tube **T** as shown is capable of supporting installation of multiple air blown optical fiber units and providing for cabling system upgrade capability. Prior art air blown fiber (ABF) tube **T** and tube cable **C** can be formed in a wide variety of sizes and tube counts in accordance with customer demands. For example, air blown fiber (ABF) tube cable **C** may comprise multiple 8 mm air blown fiber tubes **T** formed from polyethylene and

jacketed with polyethylene to form a tube cable with a finished outside diameter of 29 mm. The shortcomings of the prior art air blown fiber (ABF) tubes **T** and tube cables **C** with respect to low temperature shrinkage are described in detail in the preceding Related Art Section. Summarily, the prior art air blown fiber (ABF) tubes **T** and tube cables **C** shown in Figure 1 utilize common polyethylene compounds and conventional dimensions and configurations. The subject invention described in detail below has similar dimensions and configurations as the prior art air blown fiber (ABF) tubes **T** and tube cable **C** shown in Figure 1, but are formed from novel materials to form a composite structure as described in detail hereinafter.

Figure 2 shows improved air blown fiber (ABF) tube **10** of the present invention, which reduces low temperature shrinkage and post-extrusion shrinkage inherent in conventional air blown fiber (ABF) tube cables such as **C** shown in Figure 1 by over 50% at -40°C. Tube **10** is formed of a cross-linked polyolefin (preferably high density cross-linked polyethylene) incorporating an inorganic filler material such as chopped glass fiber, glass spheres, mica, talc, CaCO<sub>3</sub> or the like and optionally incorporating carbon black or other suitable ultraviolet (UV) stabilizer as needed for ultraviolet (UV) radiation protection. While an inorganic filler is preferred, it is contemplated that similar results may be achieved using polymeric fillers such as polyaramid, liquid crystal polymers, or engineered resin fillers either alone or in combination with the aforementioned inorganic fillers. Optimal cross-linking of the high density polyethylene forming tube **10** is in accordance with ASTM Standard D2765-95, Method A, and ranges between 40.0%-90.0% and most suitably between

65.0%-89.0%. Electron-beam, peroxide, Azo compounds, or vinyl silane may be used to initiate the cross-linking. Vinyl silane in a high temperature moisture bath is the preferred method. The optional addition of carbon black provides ultraviolet (UV) radiation resistance to tube **10** in applications where the tube is exposed to ultraviolet (UV) radiation. Preferably, the final chopped glass content of tube **10** is no greater than 5.0% by mass of tube **10**. The glass fill is preferably chopped glass fibers or microspheres. At loadings higher than 5.0%, tube **10** is susceptible to fracture at cold temperatures when bent to its minimum radius as recommended by industry and manufacturer recommendations. Use of other inorganic or organic fillers may allow the filler content to increase above 5%, however the content should be minimized to allow optional flexibility at low temperatures while maintaining the desired level of shrinkage control. A suitable size for tube **10** is  $6.00 \pm 0.10$  millimeters (mm) inner diameter by  $8.00 \pm 0.13$  millimeters (mm) outer diameter, but tube **10** may be manufactured in either smaller or larger diameters as required to accommodate optical fiber counts and tube cable designs as a matter of design choice.

The addition of chopped glass filling to air blown fiber (ABF) tube **10** creates a rough surface texture which can reduce sealing efficiency of tube couplings (not shown thereto). Thus, a smooth outer skin layer **24** comprised solely of a polyolefin or cross-linked polyolefin to increase coupling ability may be provided as shown in the air blown fiber (ABF) tube **20** depicted in Figure 3. Air blown fiber (ABF) tube **20** comprises a cross-linked polyolefin (preferably high density cross-linked polyethylene) having 5.0% or less by mass of



chopped glass therein with smooth outer layer **24** applied thereover. Layer **24**, preferably formed of cross-linked high density polyethylene, typically should be between 0.02 and 0.25 millimeters (mm) in thickness. A standard tube coupling (not shown) must be able to withstand in excess of 200 psi static pressure without leakage, and smooth outer layer **24** provides a desirable smooth sealing surface to engage with pneumatic tube couplings.

Also with reference to Figure 3, a thin inner layer **26** has been applied within tube **20** to facilitate air blown optical fiber unit blowing performance of tube **20**. Tube **20** may most suitably have an inner layer **26** comprising a polyolefin (preferably a cross-linked high density polyethylene) incorporating a maximum loading of 10% silicone lubricant for improved bundle blowing performance. Optionally, inner layer **26** may also include a chopped glass content of no greater than 5.0% by mass. Inner layer **26** is most suitably between 0.02 and 0.13 millimeters (mm) in thickness.

Referring now to Figures 4A-4D, another embodiment of the invention is shown wherein multiple air blown fiber (ABF) tubes are combined together and surrounded by a jacket **32** thereover for mechanical and environmental protection. The tubes within air blown fiber (ABF) tube cable **30** may be either tube **10** of Figure 2 or tube **20** of Figure 3 with jacket **32** extruded thereover. Figures 4A-4D depict air blown fiber (ABF) tube cable constructions comprising two, three, seven and nineteen tubes **20**, respectively. The depictions are for purposes of illustration only, and are not intended to limit the scope of the present invention which is defined by the claims appended hereto. Similar to tubes **10** and **20**, jacket **32** is comprised of cross-linked polyolefin (preferably

cross-linked high density polyethylene) incorporating carbon black or other suitable ultraviolet (UV) radiation stabilizer. Most suitably the polyethylene also includes a chopped glass content, preferably 5.0% or less, by mass of jacket **32**. Ideal cross-linking of jacket **32** is according to ASTM Standard D2765-95, Method A, and ranges between 40.0% and 90.0% and most suitably between 65.0% and 89.0%. Vinyl silane, E-beam, Azo compounds, or peroxide may be used to instigate the cross-linking of the high density polyethylene of jacket **32** in a high temperature moisture bath. The carbon black provides ultraviolet (UV) radiation stability to jacket **32**. If more than 5.0% by mass of chopped glass content is used in jacket **32**, jacket **32** may fracture at cold temperatures when bent to its minimum bend radius as recommended by industry and manufacturer recommendations. Typical thickness for jacket **32** should be about 1.50 millimeters (mm).

Referring now to Figures 5 and 6 of the drawings, it can be appreciated that dielectric or metallic strength elements **42** may be included in the air blown fiber (ABF) tube cable for additional tensile strength and buckling resistance. Preferably, strength members **42** are of rod design and not greater than 8.00 millimeters (mm) in diameter. Air blown fiber (ABF) tube cable **40** in Figures 5 and 6 also comprises outer jacket **44** and a plurality of tubes **20** (tubes **20** are shown only for purposes of illustration in the drawings and tubes **10** could also be provided in tube cable **40**), a binder or tube wrap **46** such as water blocking tape may be applied along the length of tube cable **40** to bind tubes **20** and/or to protect the core from fresh or salt water, and a conventional rip cord **48** may also be utilized in the construction of air blown fiber (ABF) tube cable **40**.

Although Figures 5 and 6 depict six and eighteen tube cables, the number of tubes is a matter of design choice and the constructions shown in Figures 5 and 6 are not intended in any manner to limit the scope of the present invention, the invention being defined by the claims appended hereto.

5           Table 1 set forth hereinbelow illustrates the reduction in low temperature shrinkage and post-extrusion shrinkage provided by the tube of the present invention in contrast to currently available air blown fiber tubes. The information shown in Table 1 is formed as follows: Row 1 is a mono-wall construction tube of prior art high density polyethylene (HDPE) with 6.0 mm  
10           inside diameter and 8.0 mm outside diameter. Row 2 is a cross-linked high density polyethylene (HDPE) tube with 6.0 mm inside diameter and 8.0 mm outside diameter. Row 3 is the tube described by the present invention using cross-linked high density polyethylene (HDPE) and chopped glass fill with 6.0 mm inside diameter and 8.0 mm outside diameter. The measurements are  
15           taken as follows: Thermal Mechanical Analysis (TMA) was used to test low temperature shrinkage and post-extrusion shrinkage. Low temperature shrinkage was the average value of shrinkage seen at -40°C. Post-extrusion shrinkage was calculated as the percentage of shrinkage remaining after one complete temperature cycle between +75°C and -55°C, starting at and then  
20           returning to room temperature (+20°C) with a temperature ramp of 3°C/min.

Table 1

Material	Low Temperature Shrinkage at -40C (%)	Post-Extrusion Shrinkage (%)
HDPE	1.88	0.77
Cross-linked HDPE	0.71	0.22
Cross-linked HDPE with 3.75% chopped glass	0.47	0.14

As can be appreciated with reference to the table, low temperature shrinkage and post-extrusion shrinkage is reduced by greater than 50% by the air blown fiber (ABF) tube construction of the present invention by utilizing cross-linked high density polyethylene for the cable polymer materials, and significantly more by using cross-linked high density polyethylene with chopped glass as taught herein in the complete cable structure.

Method of Manufacture

Presently, conventional air blown fiber (ABF) tubes exhibit a high coefficient of thermal expansion. Typically, this coefficient of thermal expansion causes tube contraction as high as 2.0% or more over the cable lifetime through the typical outside ambient temperature range. Thus air blown fiber (ABF) tubes are seldom used for these applications since loops have to be installed at each end of the run to accommodate the length change in the cable tubes as the temperature changes. For example, ten foot loops would have to be installed at each end of a one thousand foot run of conventional air

blown fiber (ABF) tube cable to accommodate the high coefficient of thermal expansion values of the tube cable assembly.

The present invention provides for a mono wall tube **10** (Figure 2) or multilayer wall tube **20** (Figure 3) as well as corresponding tube cables **30** (Figure 4A-4D) and **40** (Figures 5 and 6) that will exhibit a coefficient of thermal expansion value of less than 150  $\mu\text{m}/\text{m}^\circ\text{C}$ . A preferred construction of the invention is multilayer tube **20** shown in Figure 3 comprising an inner layer or liner **26** formed of a silicone lubricated cross-linked high density polyethylene. This material can be a custom compound or a dry blend of materials that are blended at the extruder by volumetric or gravanometric blending prior to being placed into an extruder. Optionally, inner layer **26** may also include a chopped glass content, preferably 5.0% or less by mass. Central layer **22** of tube **20** makes up the bulk of tube **20** and is comprised of cross-linked high density polyethylene and chopped glass strands and may include carbon black or other suitable ultraviolet (UV) radiation stabilizer. The material may be a custom compound or a dry blend of the polyethylene and a glass master batch (raw short glass fiber incorporated into the polyethylene). The addition of 5.0% or less by mass of the short glass strands serves to reinforce the polymer with more thermally stable glass material. Outer layer **24** of tube **20** is formed from cross-linked high density polyethylene, and outer layer **24** serves to allow the use of push-to-connect (PTC) fittings to make connections and splices in the tube and/or tube cables during routing and installation. Without outer layer **24**, the surface of tube **20** could be too rough to allow the fittings to seal and maintain air pressure.

Mono wall tube **10** or multilayer tube **20** can be manufactured in a continuous operation utilizing a single extruder for mono wall tube **10** or a multilayer extrusion process for composite tube **20**. In each construction the line speed and draw ratios will be optimized to limit the amount of post-extrusion stresses imparted to the tubing during processing since this parameter significantly affects the expansion and contraction values of finished tubes **10** and **20**. Tubes **10** and **20** may incorporate carbon black or other suitable ultraviolet (UV) radiation stabilizer to provide ultraviolet (UV) stability and degradation protection to the product for long term reliability.

Referring now to Figures 4-6, after tube **10** and tube **20** are formed, various tubes can be made in configurations ranging from single tube applications to more complex two through nineteen tube cable constructions (see Figures 4A-4D). The resulting tube cables will be either of a planetary cabled, SZ cabled and/or parallel construction. The tube core may be wrapped with a water-blocking means. The preferred embodiment utilizes a flat, water-swellaable tape, which may be applied spirally or longitudinally around the individual tubes **10** or **20** and/or around the cluster of tubes **10** or **20** forming the cable core. Over the cluster of tubes **10** or **20** an outer sheath or jacket **32** (see Figures 4A-4D) and **44** (see Figures 5 and 6) is applied to form tube cables **30** and **40**, respectively, which meets the same design criteria for thermal expansion as do tube **10** and tube **20**. Jacket **32** and **44** are formed from a cross-linked high density polyethylene and chopped glass compound similar or identical to that used in tube **10** and tube **20**. Also, jacket **32** and **44** incorporate carbon black or other suitable UV stabilizer similar to that used in

tube **10** and tube **20** to provide ultraviolet (UV) stability and degradation protection.

It will be understood that various details of the invention may be changed without departing from the scope of the invention. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation--the invention being defined by the claims.

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